The JPL RL06 GRACE Gravity Solutions

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Helmholtz Centre Potsdam – GFZ German Research Centre for Geosciences

Potsdam, Germany

Jet Propulsion Laboratory
California Institute of Technology

GSTM, Potsdam, Germany, 9-11 October 2018

Data Overview
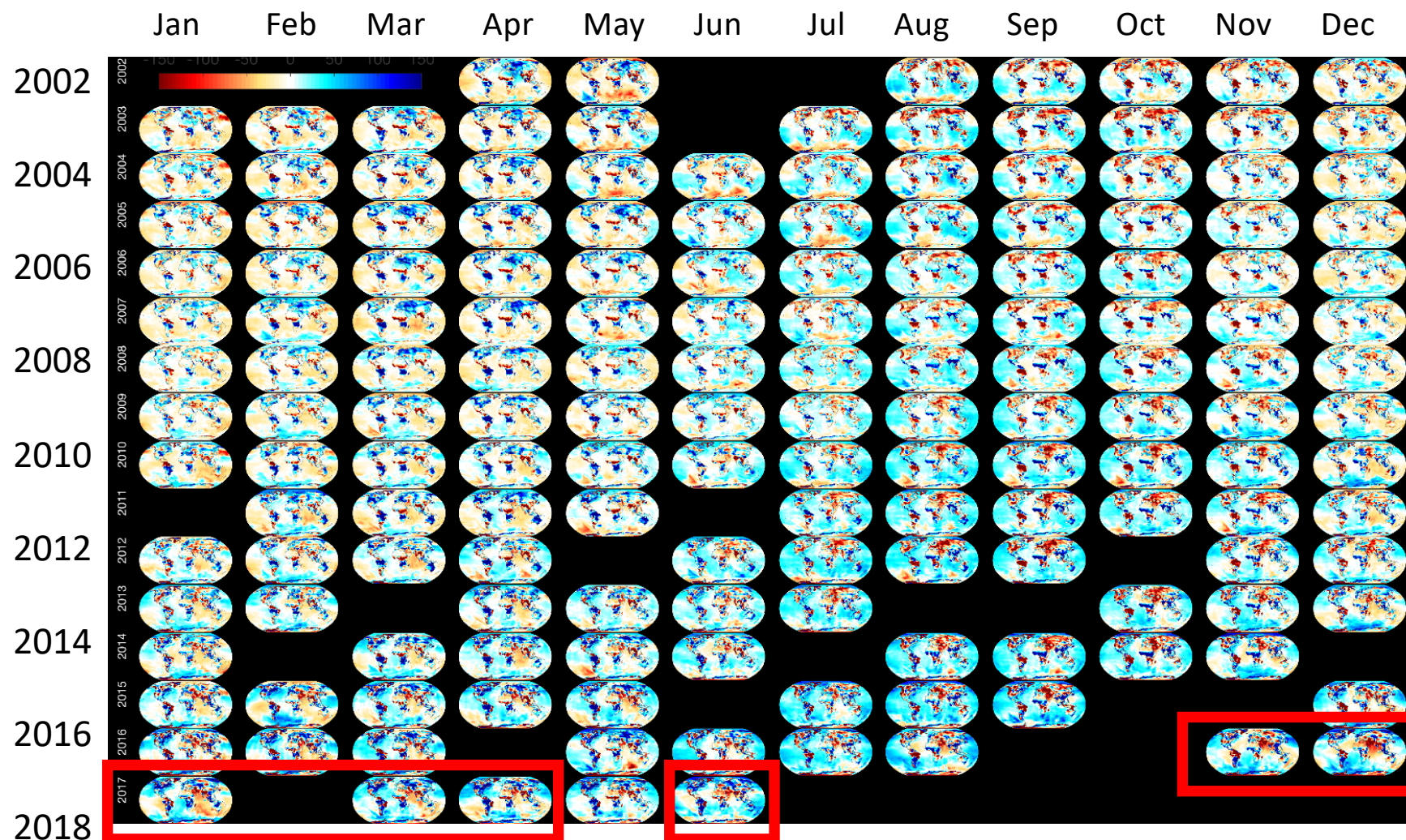
163 monthly solutions

Months with only
GRACE-A
Accelerometer Data

RL06 Data Products

- Unconstrained Monthly Spherical Harmonic Solutions
  - Ideology – attempt to do as little to the raw data as possible
  - 60 x 60
  - 96 x 96
  - 60 x 30 in months with deep repeat orbits
  - New filename definitions and YAML headers
  - April 2002 – June 2017 are released

- Constrained 3° Spherical Cap Mascon Solution
  - Ideology – retain all signals while removing as much correlated error as possible
  - Solution with Coastline Resolution Improvement (CRI) Filter
  - Solution without CRI Filter
  - Calibrated errors are provided
  - NetCDF format
  - Full timeseries is available

- Solutions can be accessed through PODAAC or GRACE Tellus (grace.jpl.nasa.gov)

Data and Parameterization

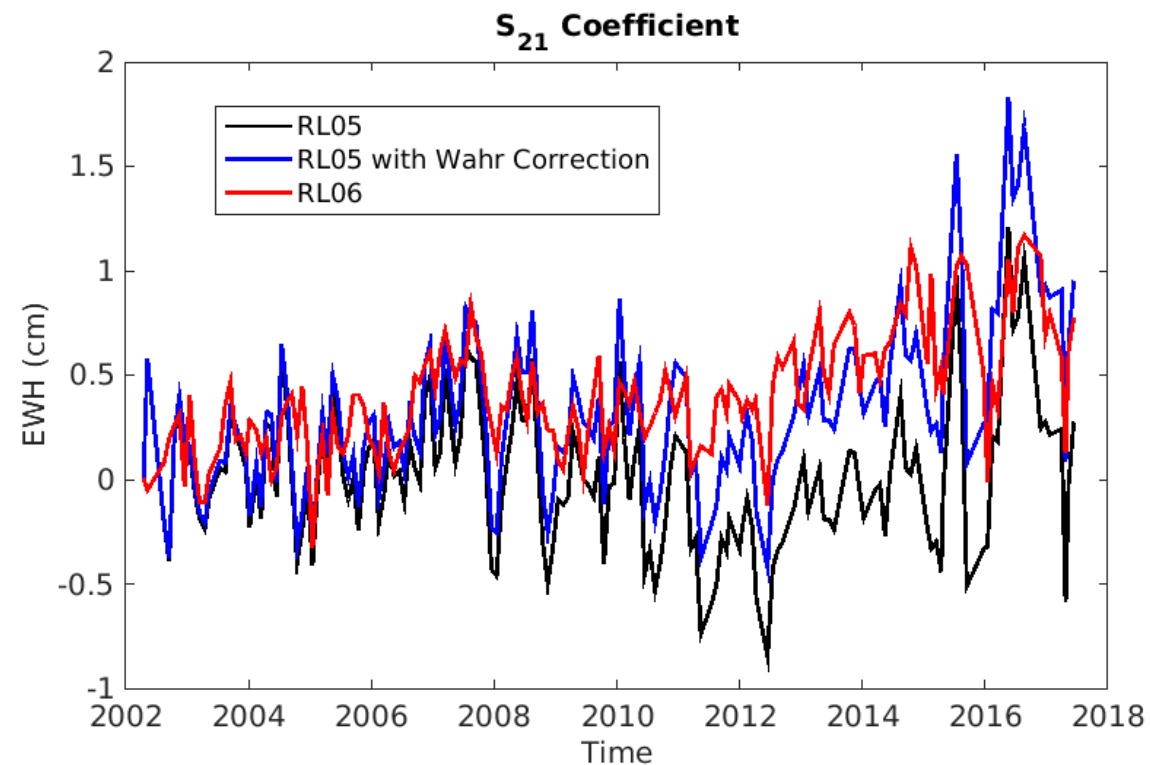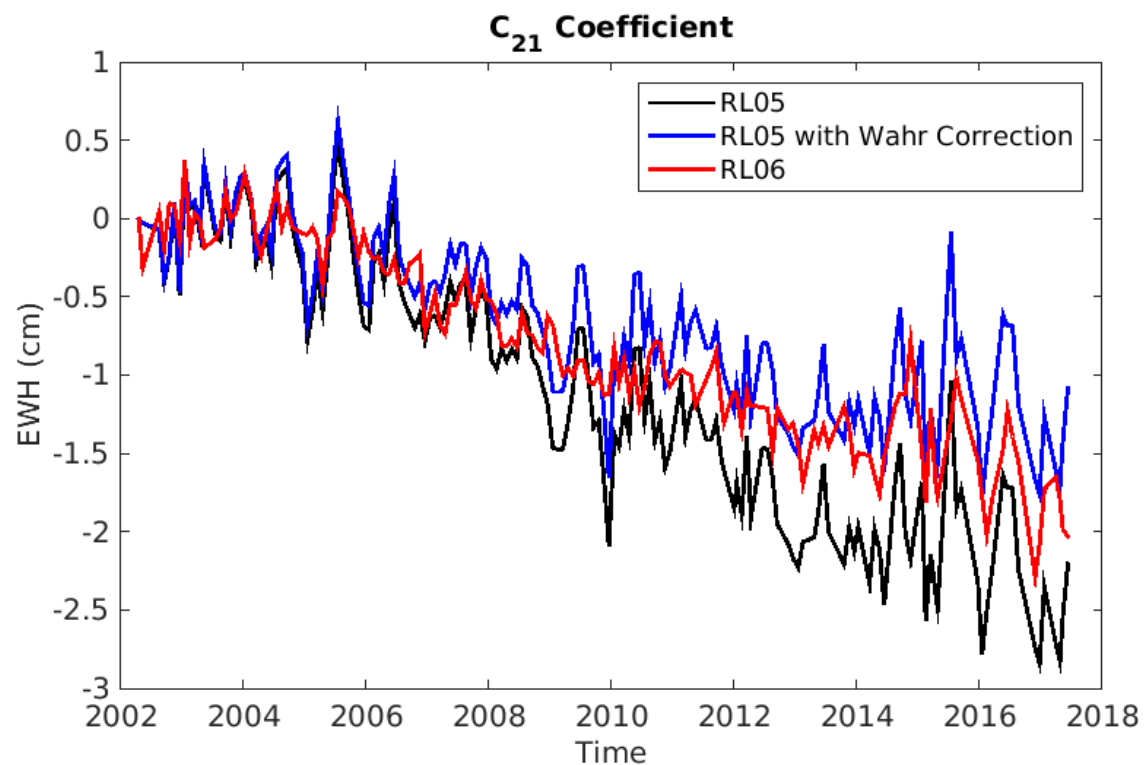|		RL05	RL06
Data Used *Only for Single Accelerometer months	Harmonics	ACC1B V02 (5-second rate) KBR1B V02 (5-second rate) SCA1B V02 (5-second rate) GPS1B V02 (300-second rate)	ACC1B V02 (5-second rate) **KBR1B V03 (5-second rate)** **SCA1B V03 (5-second rate)** **GPS1B V02 (30-second rate) - downweighted** ***ACT1B V02 (5-second rate)**
	Mascons	ACC1B V02 (5-second rate) KBR1B V02 (5-second rate) SCA1B V02 (5-second rate)	ACC1B V02 (5-second rate) **KBR1B V03 (5-second rate)** **SCA1B V03 (5-second rate)** **GPS1B V02 (30-second rate) - downweighted** ***ACT1B V02 (5-second rate)**
Parameterization *Only for Single Accelerometer months	Harmonics and Mascons	Satellite States: once per day; GPS phase biases: once per pass; KBR range-rate empirical biases/drifts/once-per-rev: 90 min; Accelerometer Biases/Rates: X and Z daily, Y is 3 hourly; *Empirical accelerations (constant, once/rev) every 90 min in alongtrack and crosstrack	Satellite States: once per day GPS phase biases: once per pass KBR range-rate empirical biases/drifts/once-per-rev: 90 min Accelerometer Biases/Rates: X and Z daily, Y is 3 hourly **Full Accelerometer Scale Matrix: daily (Klinger et al., 2016)** *Empirical accelerations (constant, once/rev) every 90 min in alongtrack and crosstrack

Background models

	RL05	RL06	Remarks
Static Field	gif48 180x180	ggm05c 360x360	Epoch changes from 01/07 to 01/08; earthquakes included in the static field
Atmosphere/Ocean Dealiasing Product	AOD RL05 6-hr, 100x100	AOD RL06 3-hr, 180x180	GAE, GAF, GAG products no longer needed
Ocean Tides	GOT4.7 90x90	FES2014 180x180	Changes from 90x90 to 180x180
Air Tides	Ray and Ponte, 2003	Ray and Ponte, 2003	S1 and S2, 100x100
Mean Pole	IERS2010	Linear Mean Pole (*Ries*, 2017)	Correction to C_{21}/S_{21} recommended by *Wahr et al.* (2015) is no longer needed
N-body Perturbations	DE421	DE430	

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C21/S21

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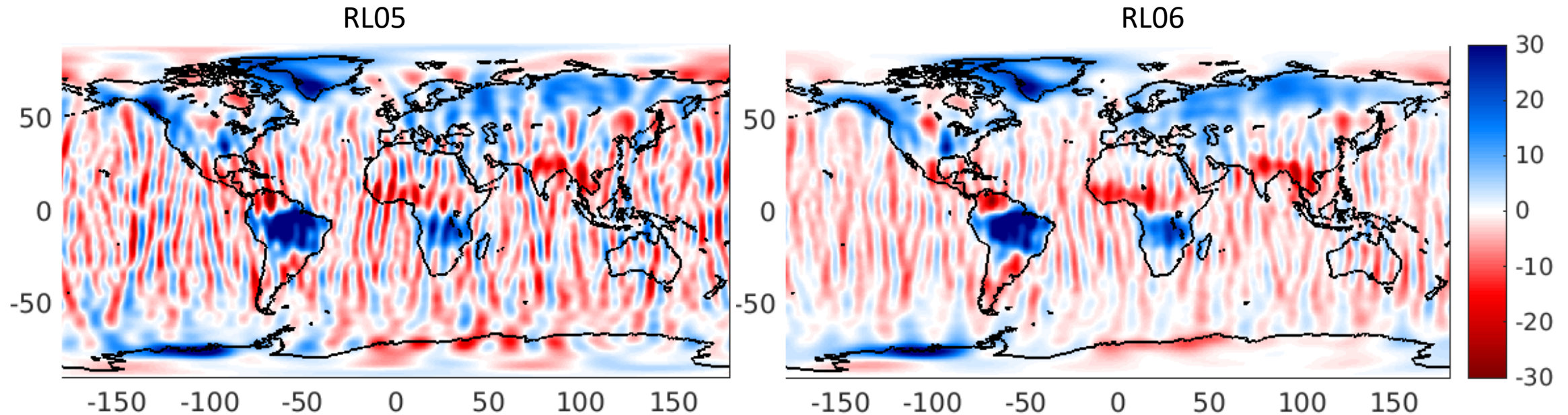
Solution Quality: RL05 to RL06

Average over all GRACE months
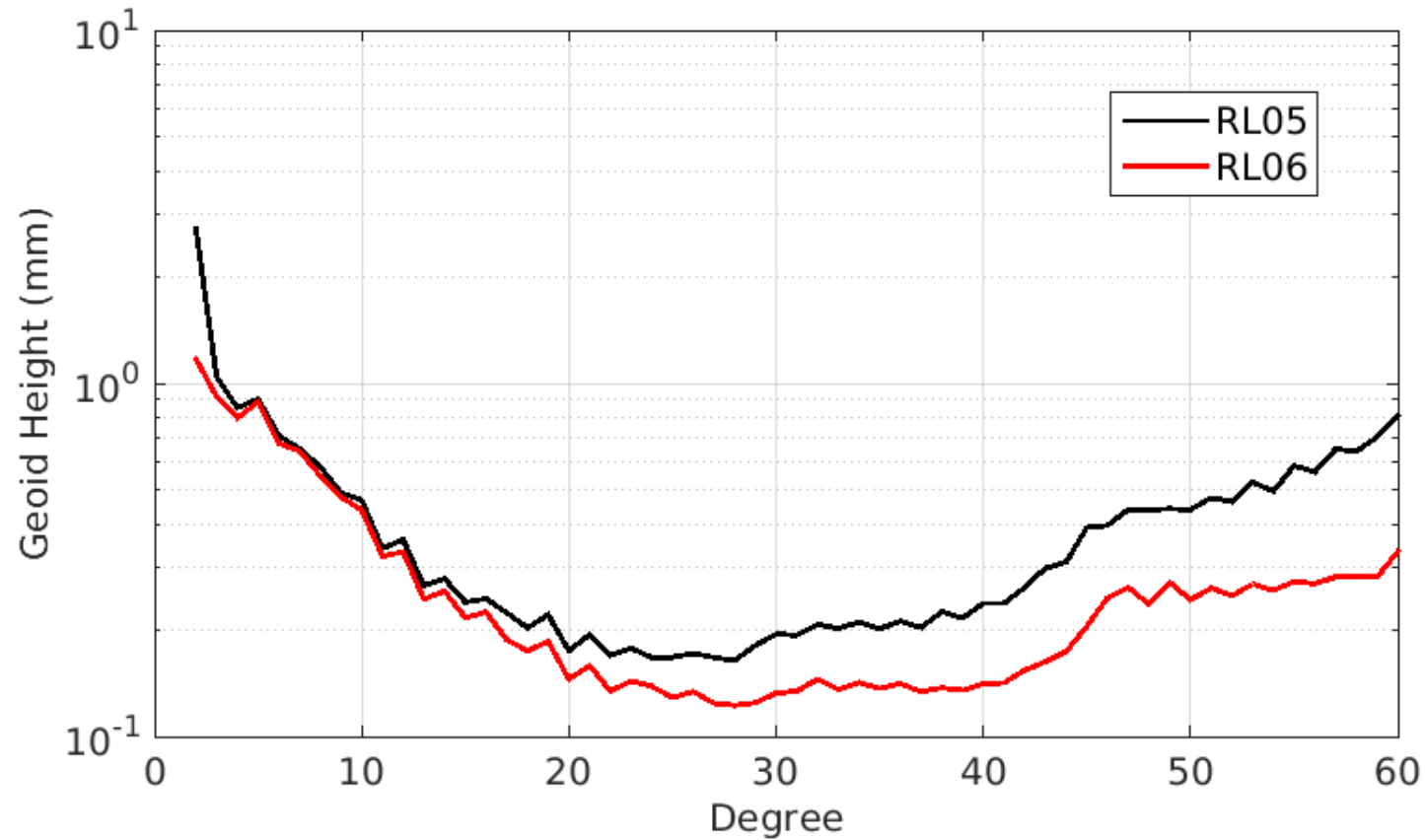
Solution Quality: RL05 to RL06
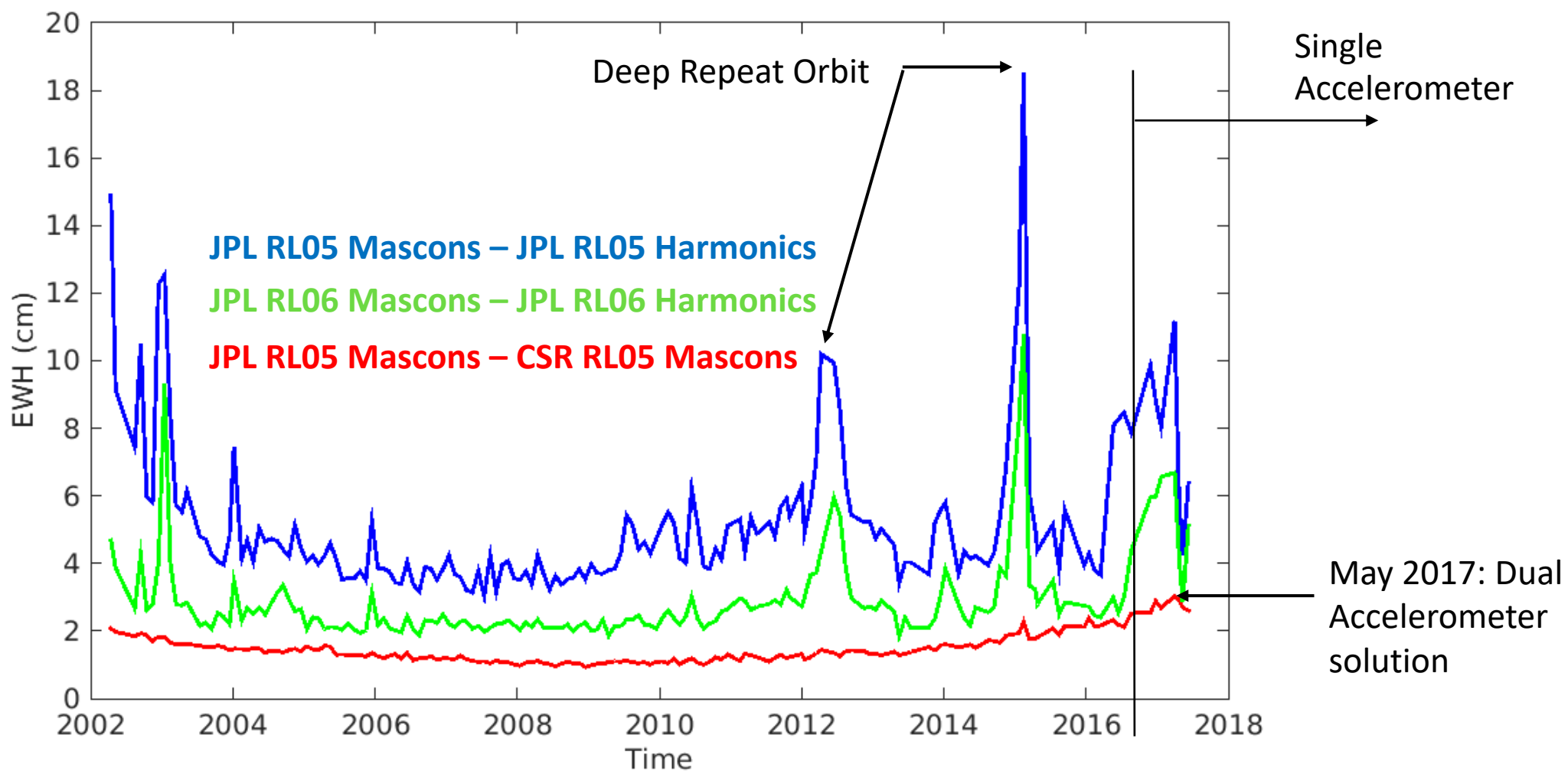
April 2008 with 300 km Gaussian smoothing

RL05

RL06

Solution Quality

Global Spatial RMS of monthly differences between JPL Mascons: Smoothed at 300 km

JPL RL05 Mascons – JPL RL05 Harmonics
JPL RL06 Mascons – JPL RL06 Harmonics
JPL RL05 Mascons – CSR RL05 Mascons

Deep Repeat Orbit

Single Accelerometer

May 2017: Dual Accelerometer solution

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Single Accelerometer Months

Two accelerometer Solution
Single accelerometer Solution
⭐ Pitch Bias introduced

| Jul | Aug | Sep | Oct | Nov | Dec | 2016 |

| Jan | Feb | Mar | Apr | May | Jun | 2017 |
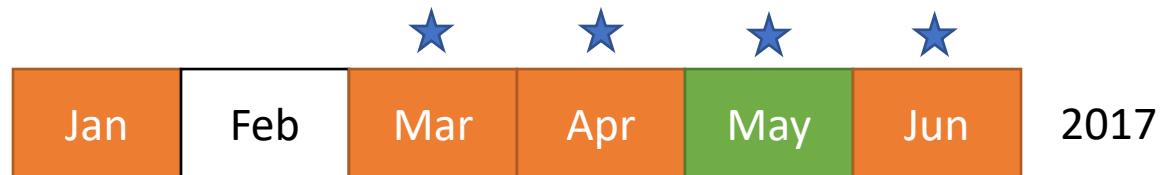
RL06 uses an improved accelerometer transplant from GRACE-A to GRACE-B which accounts for thruster firings on GRACE-B. (Bandikova et al., in review)

Average over single accelerometer months
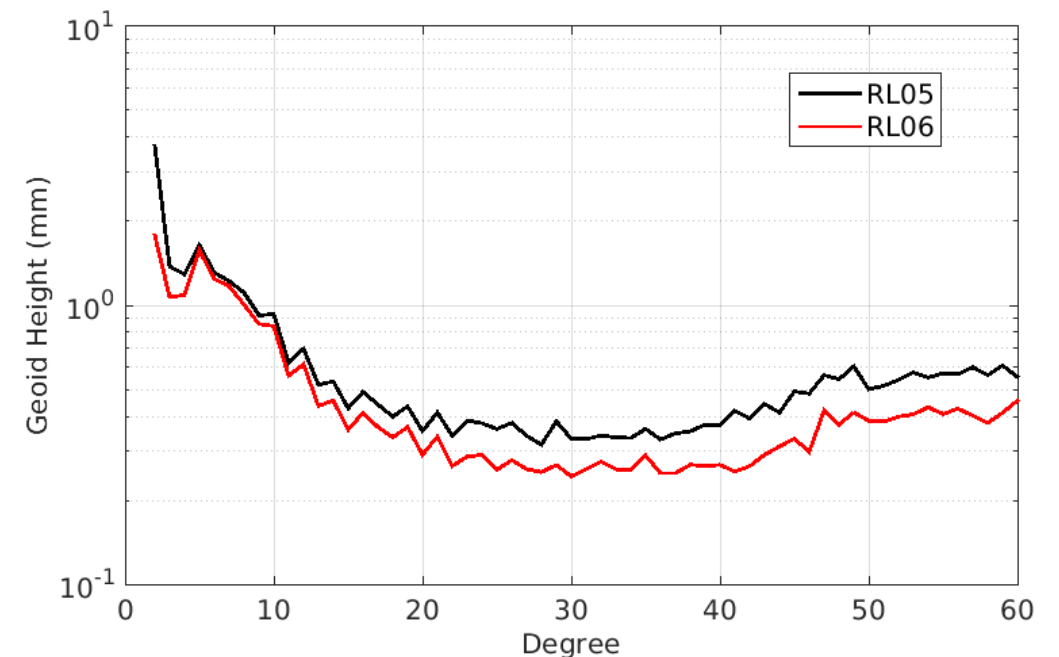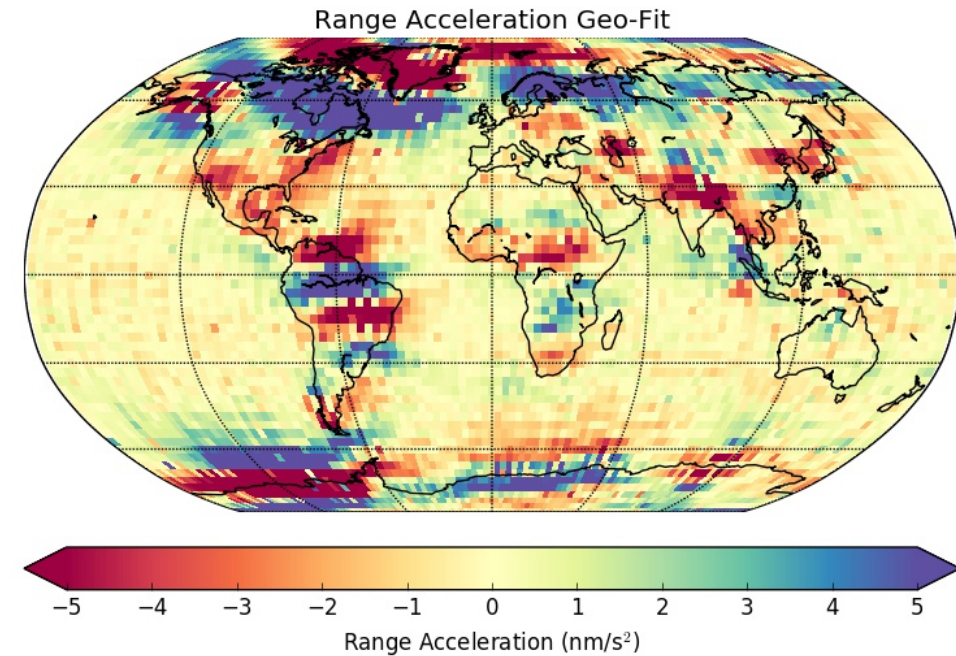
Pitch Bias degradation is reduced (May 2017)

RL05: V02 Level-1 Data
Errors manifest in zonal harmonics leading to latitudinal banding in the gravity field
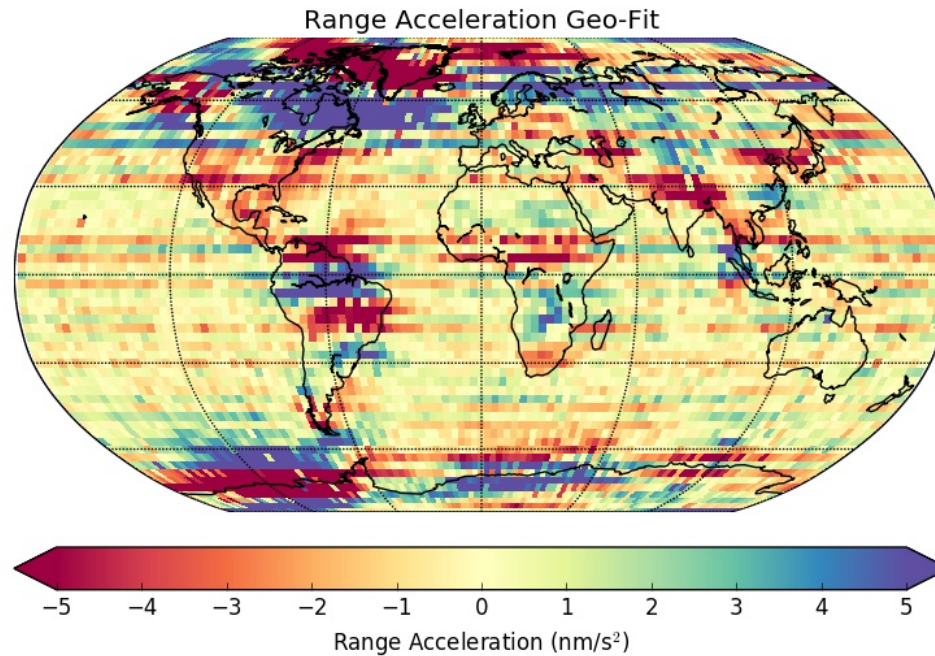
RL06: V03 Level-1 Data
Reduced high frequency noise in the attitude improves the solution

Range Acceleration Geo-Fit

Range Acceleration (nm/s²)

Range Acceleration Geo-Fit

Range Acceleration (nm/s²)

GEO-FIT plots: monthly gravity field correction mapped into range accelerations

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Single Accelerometer – Low Degrees

Low degrees have improved in RL06, but still some problems with C_{30}

Single Accelerometer

Cos Degree 3, Order 0

Legend:
— RL06 Harmonics
- - - Climatology Fit
* Residual about fit
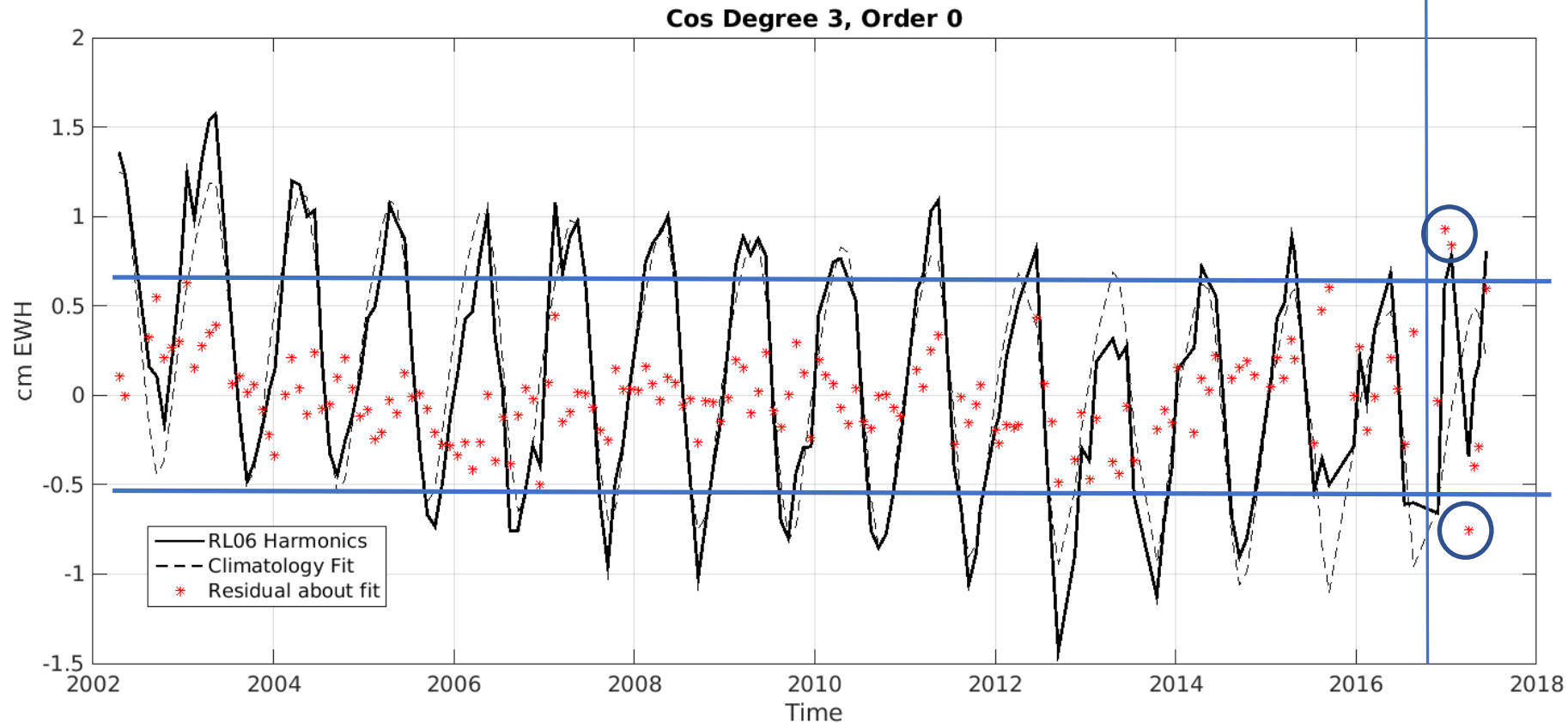
Single Accelerometer – Low Degrees

Low degrees, including C_{30}, are well behaved in mascon solution

Single Accelerometer

Cos Degree 3, Order 0

RL06 Mascons
Climatology Fit
* Residual about fit
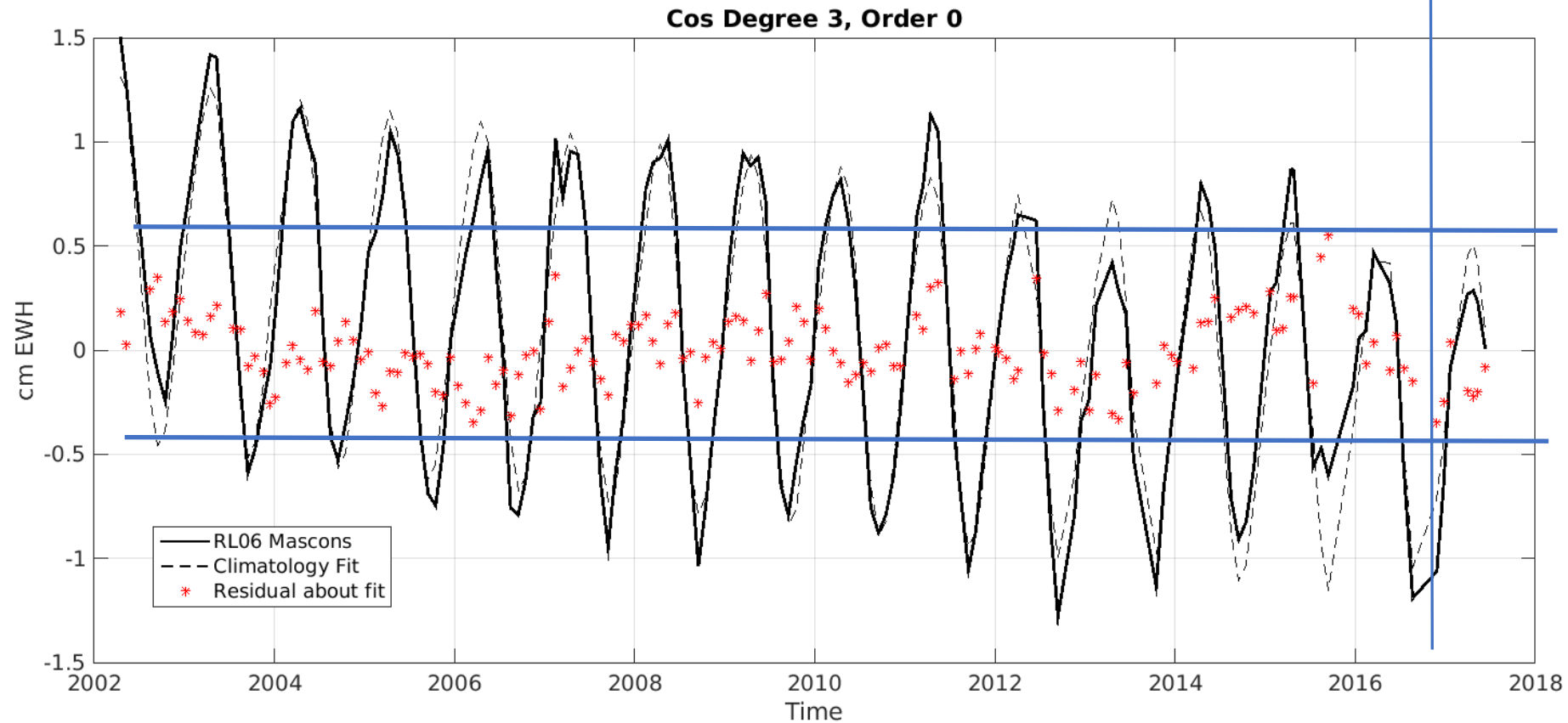
RL06 Mascon Strategy

- RL06 processing strategy is fundamentally the same as RL05 (*Watkins et al.,* 2015)
- Improvements made
  - Addition of GPS normal equations
  - Full Accelerometer Scale Matrix is estimated daily
  - Change in the GIA forward model to ICE-6GD (*Peltier et al.*, 2017)
  - Relaxation in initial conditions (apriori uncertainty) for time correlation run
  - Earthquake constraints have improved

t_o

t_n

t_o

t_n

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C$_{20}$
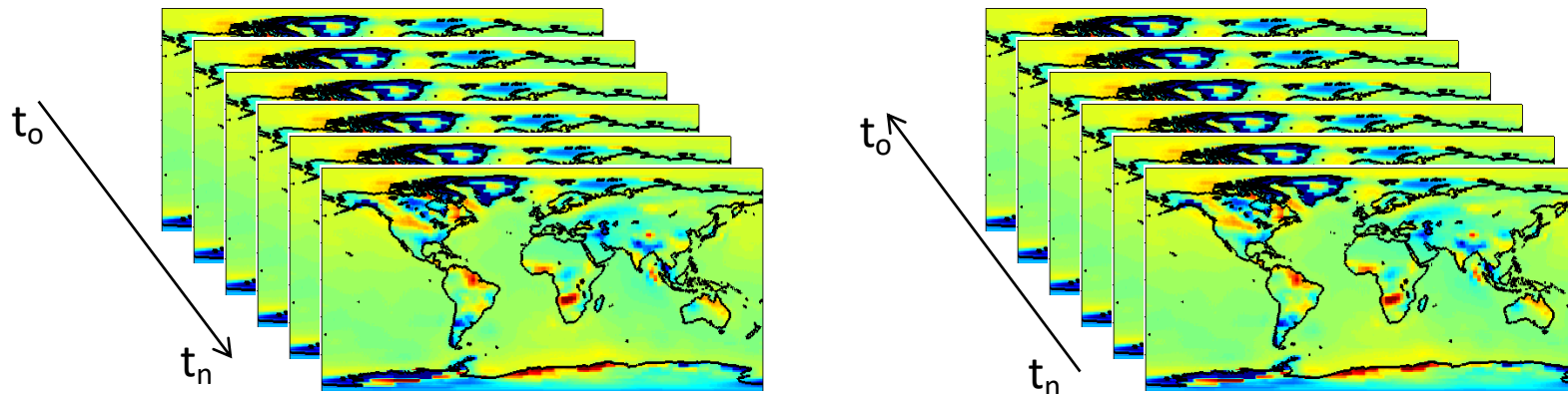
Mascons provide a "reasonable" estimate for C$_{20}$. The difference in trend with SLR (Cheng et al., 2013) is not well understood, however. We still replace the C$_{20}$ coefficient with SLR values because of this.

Cos Degree 2, Order 0
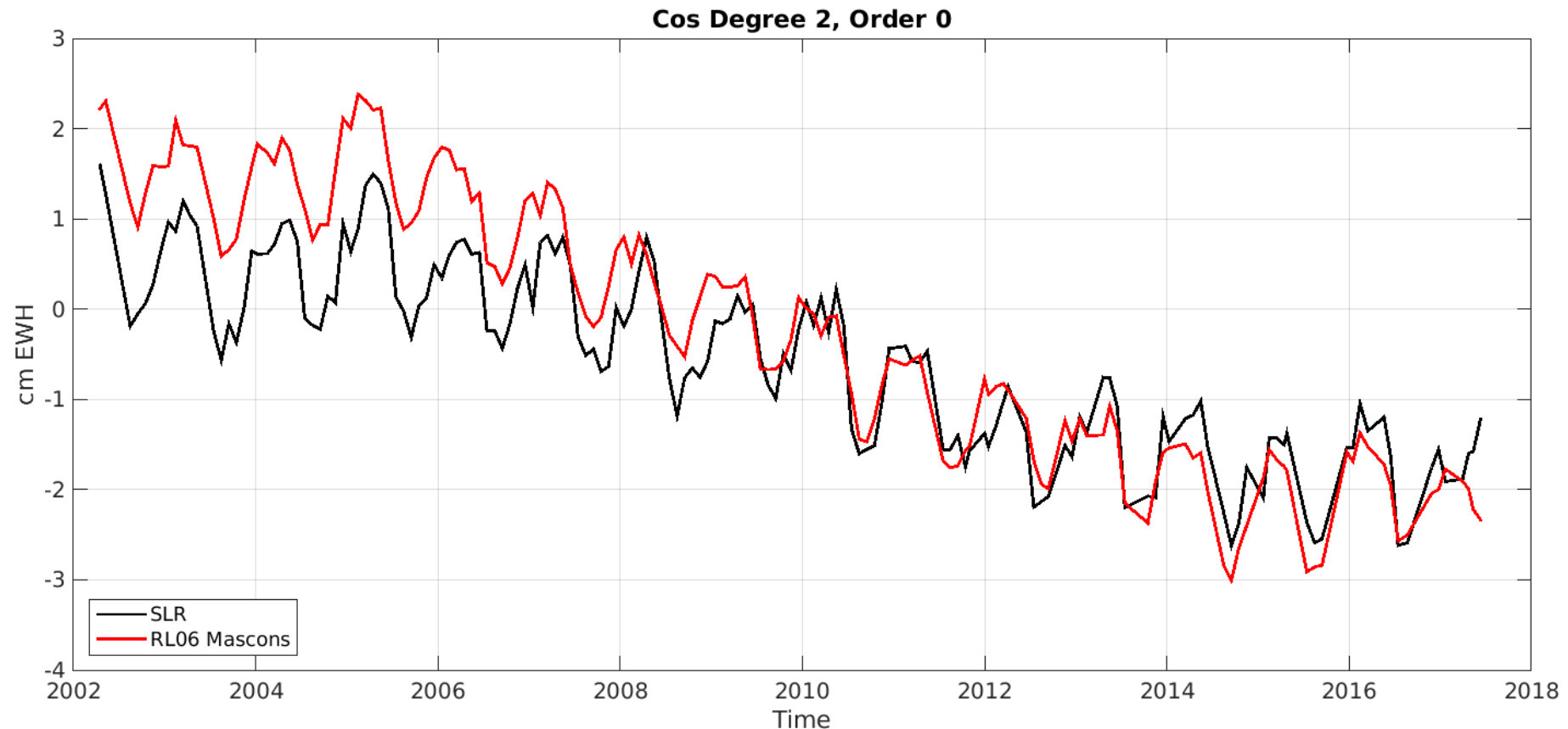
Correlation with AMOC

We compare transport in the Lower North Atlantic Deep Water with the in-situ RAPID array using methods from *Landerer et al.* (2015)
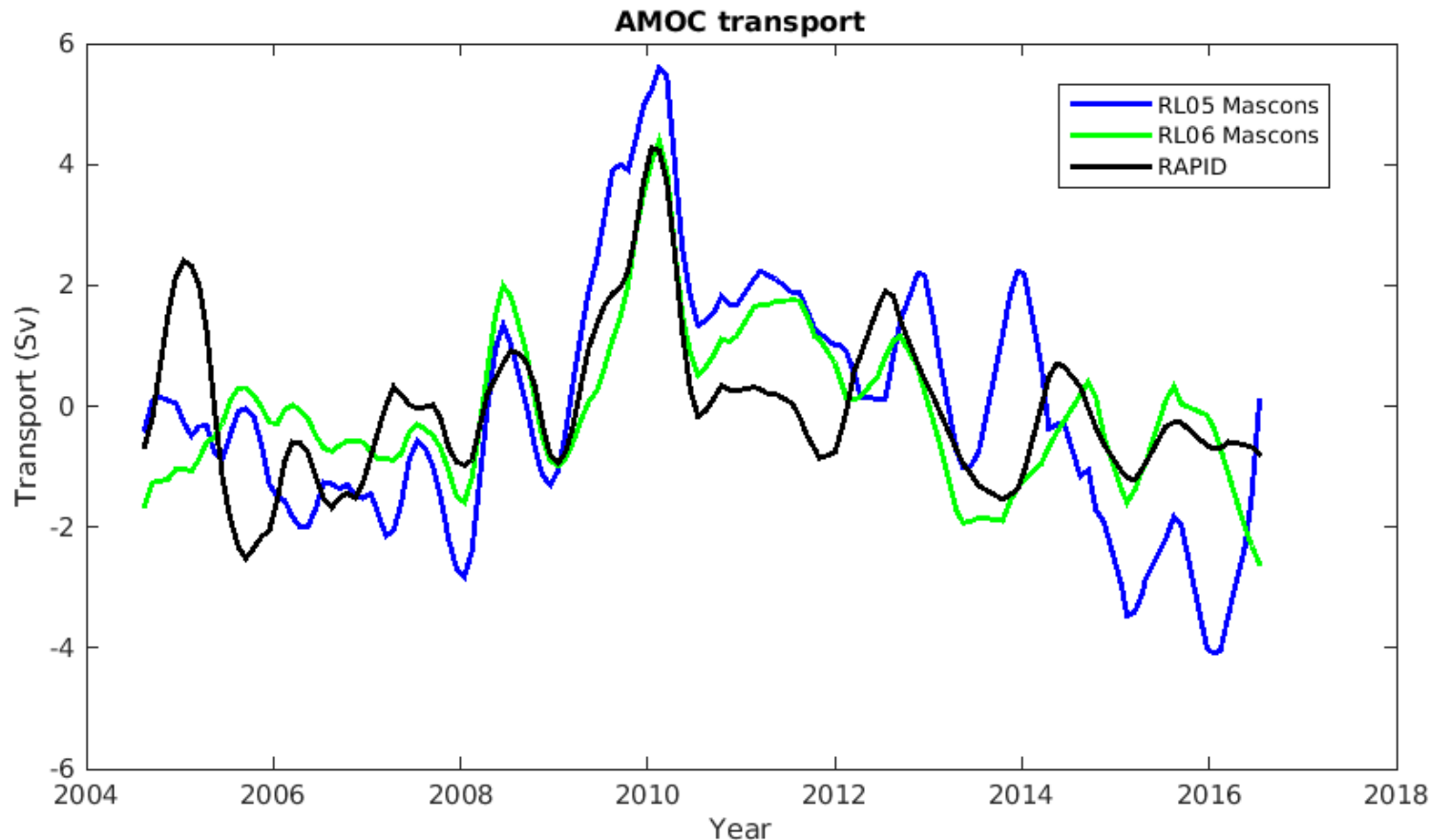
Correlation changes from 0.63 to 0.61

RMS relative to RAPID array decreases from 1.58 Sv to 1.14 Sv.

Comparison with BPRs: RL05 vs RL06

Correlation with in-situ data
Global improvement in correlation coefficient: 0.02
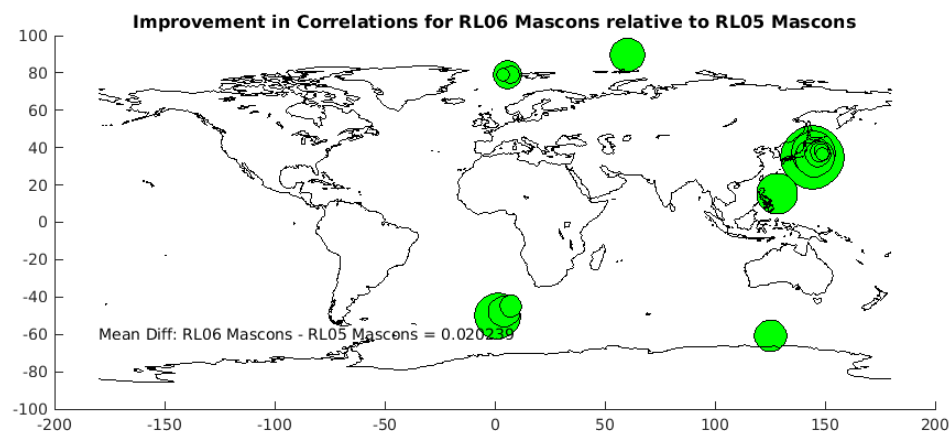
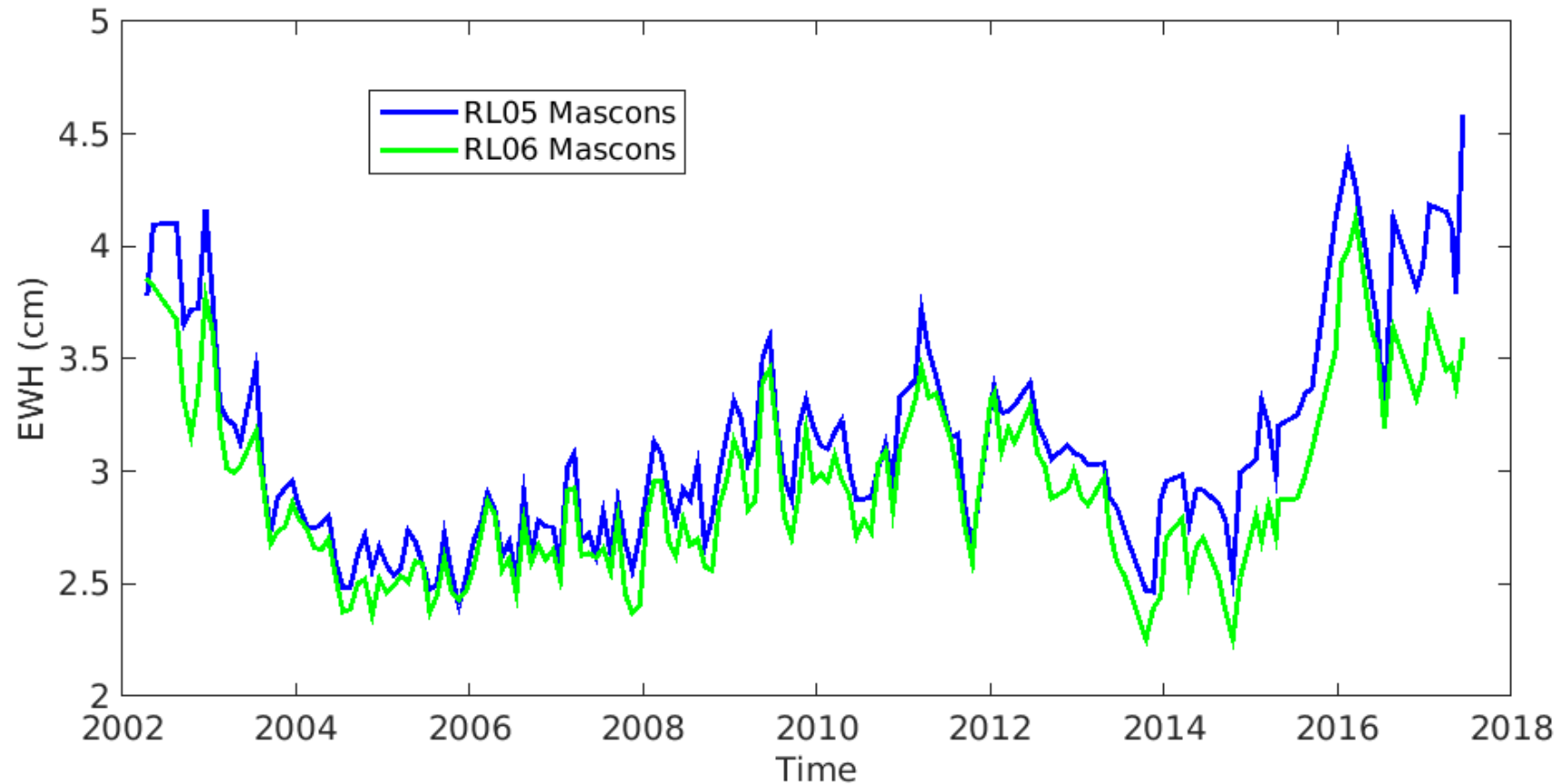### RMS relative to in-situ data
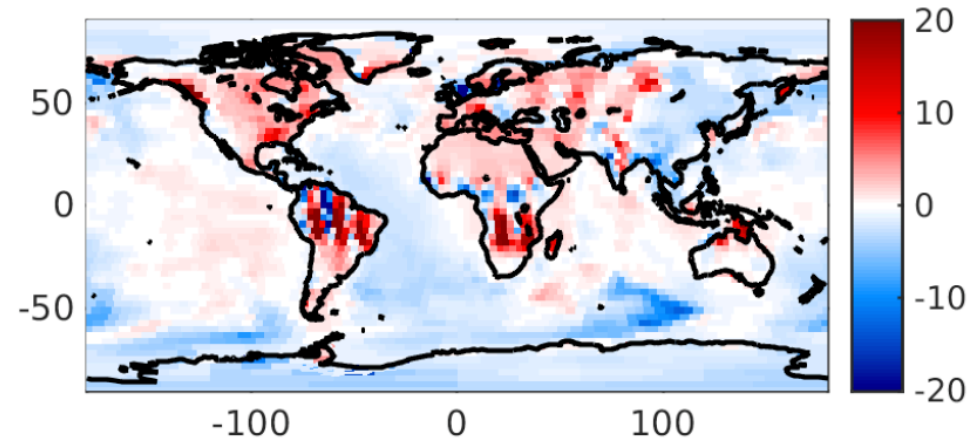*Global improvement in RMS reduction: 0.5 mm*
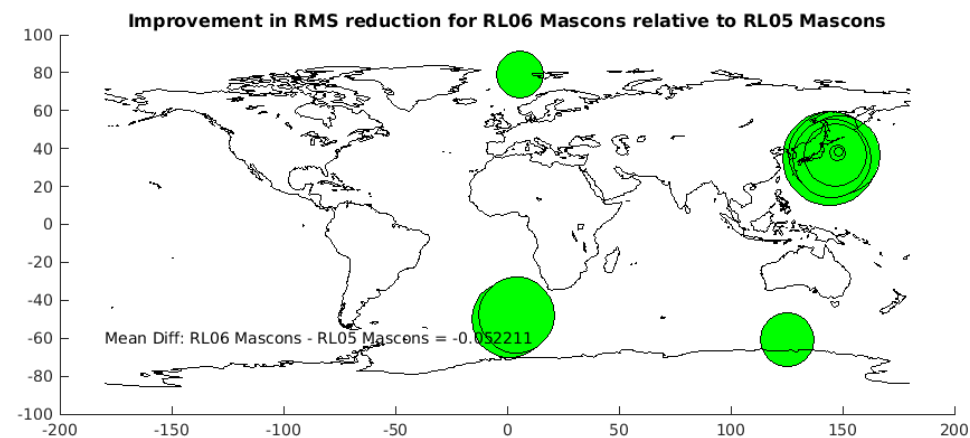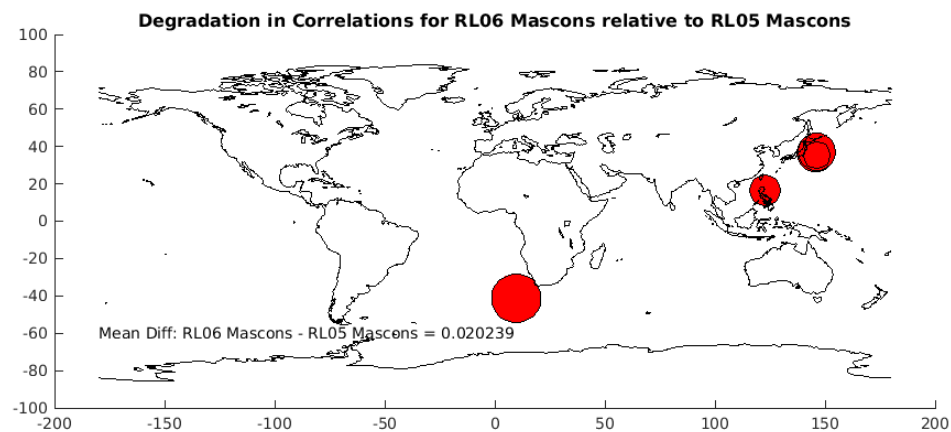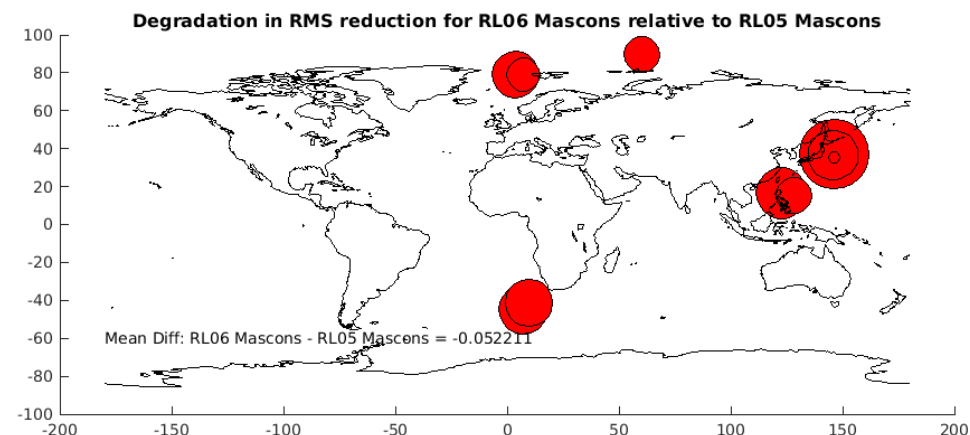
RL05 vs RL06 Mascons

Monthly residuals about a climatology fit to the timeseries
We attribute the slight reduction in residuals in RL06 to a decrease in noise in the solution
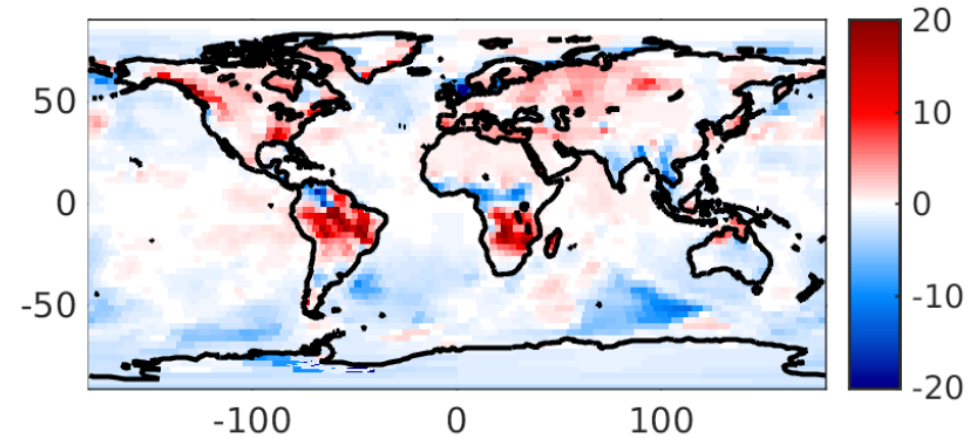
RL05 vs RL06 Mascons
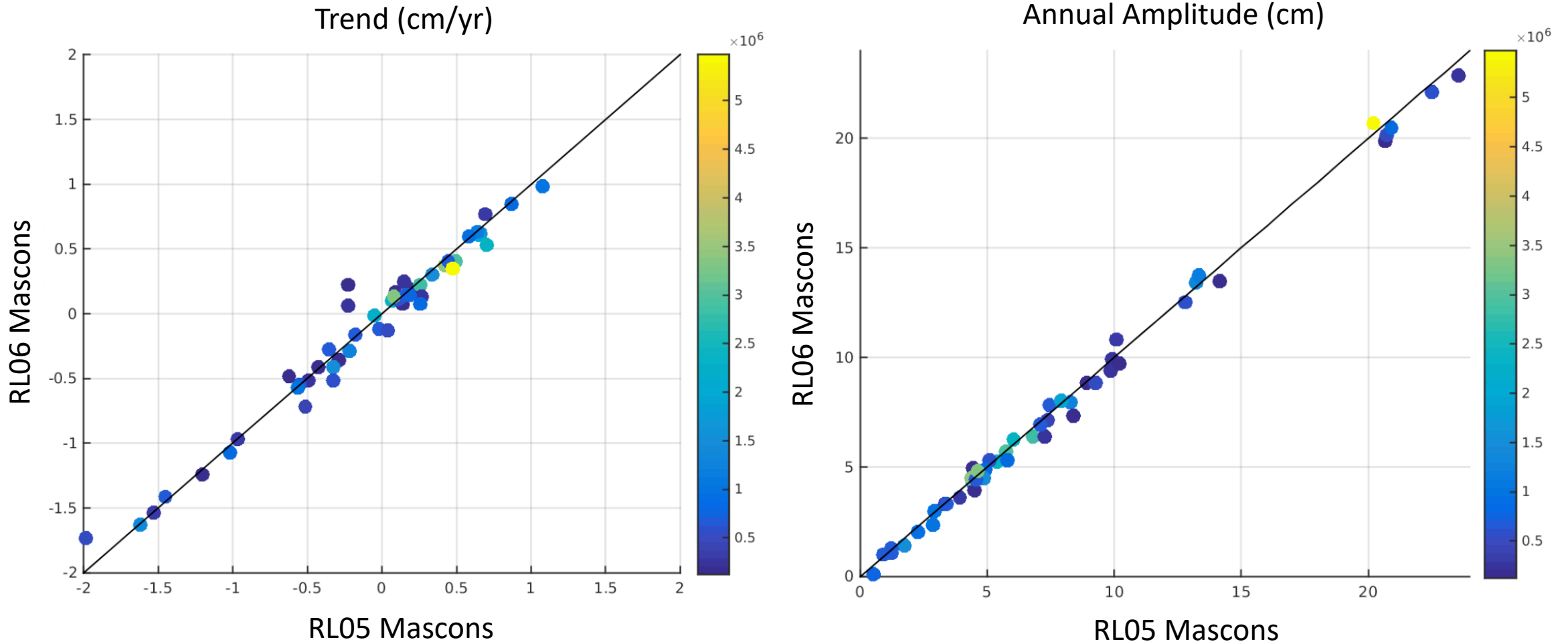
RL05: Jan 2014 – Dec 2013
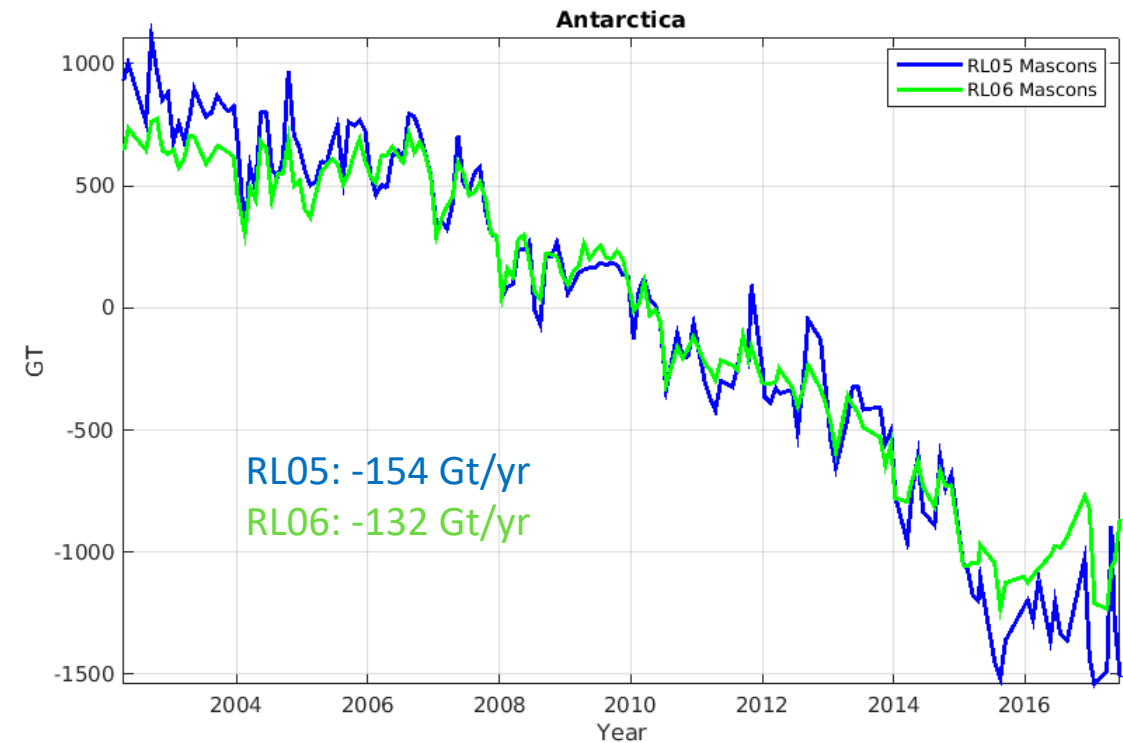

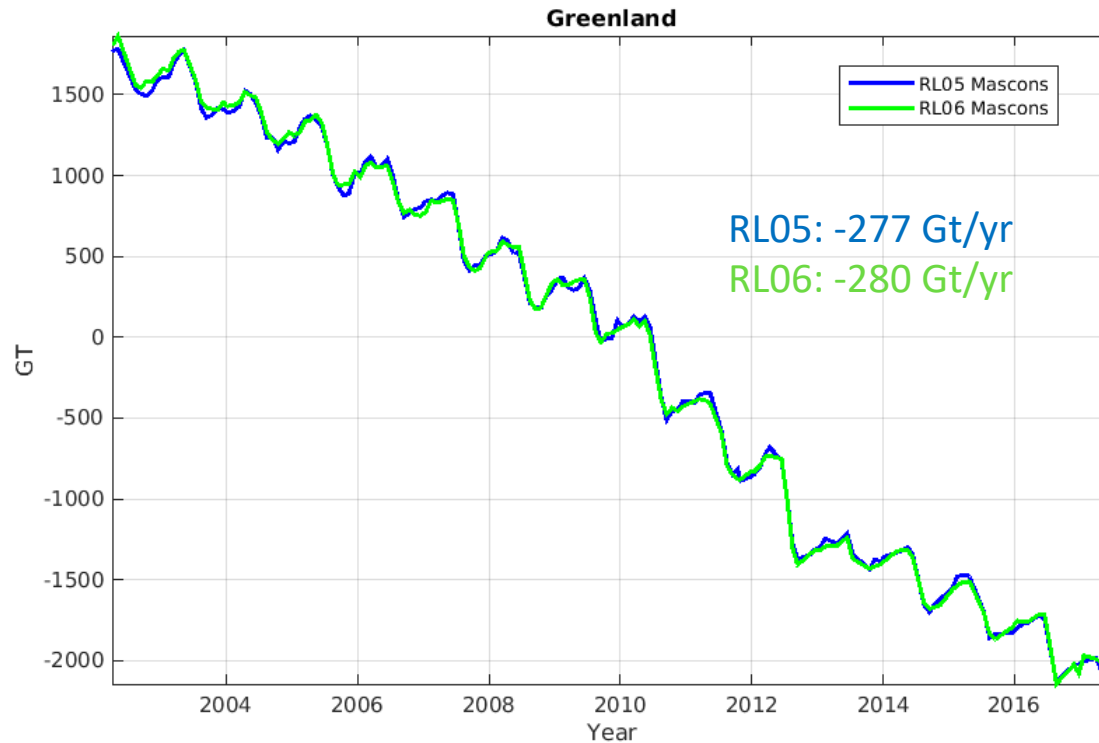**RL06: Jan 2014 – Dec 2013**

RL05 vs RL06 Mascons

Comparison over 50 hydrological basins

Trend (cm/yr)

Annual Amplitude (cm)

Ice Sheets: RL05 vs. RL06

Greenland

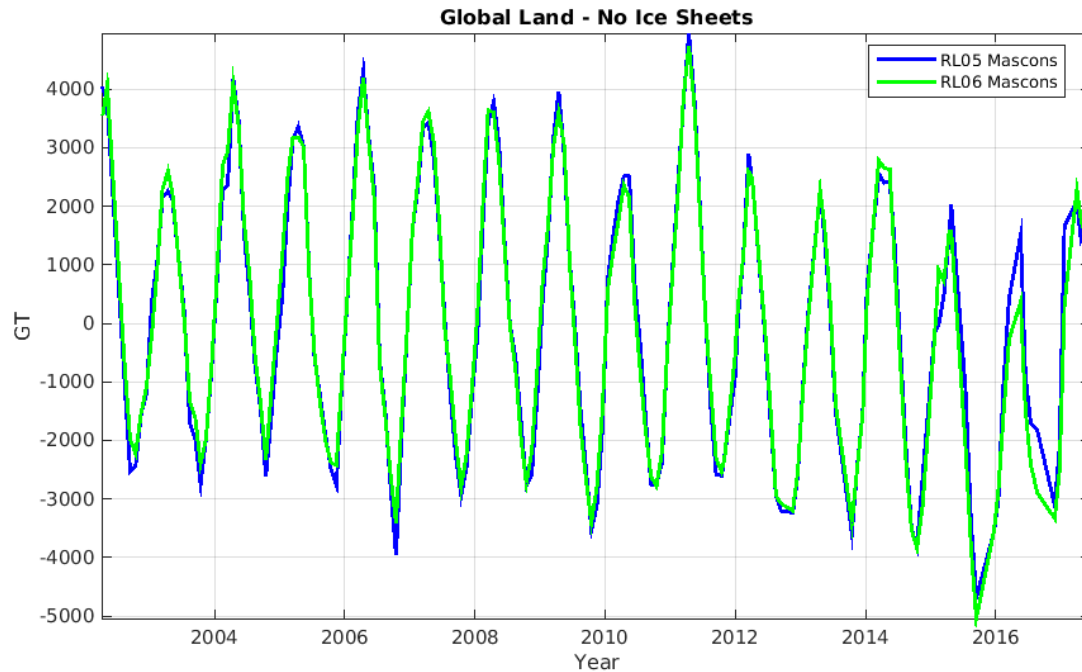RL05: -277 Gt/yr
RL06: -280 Gt/yr

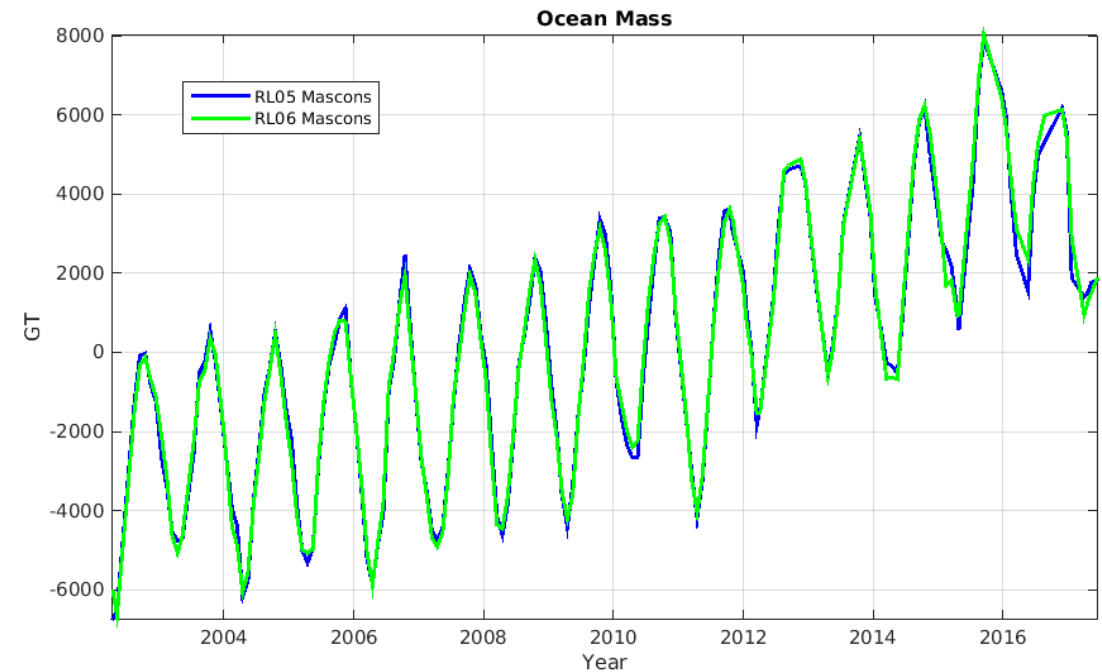**Antarctica**

RL05: -154 Gt/yr
RL06: -132 Gt/yr

Note: RL05 implements *Wahr et al.* (2015) correction and AOD jump corrections (GAE, GAF, GAG). Both solutions remove ICE-6GD GIA.

Land/Ocean: RL05 vs. RL06

Global Land - No Ice Sheets

Legend:
- RL05 Mascons (blue)
- RL06 Mascons (green)

Y-axis: GT, X-axis: Year

Ocean Mass

Legend:
- RL05 Mascons (blue)
- RL06 Mascons (green)

Y-axis: GT, X-axis: Year

RL05: -0.33 mm SLE/yr
RL06: -0.42 mm SLE/yr

RL05: 1.59 mm SLE/yr
RL06: 1.62 mm SLE/yr

Note: RL05 implements *Wahr et al.* (2015) correction and AOD jump corrections (GAE, GAF, GAG). Both solutions remove ICE-6GD GIA.

Conclusions

- JPL RL06 Data products for full GRACE data record will soon be available

- RL06 Unconstrained Harmonics represent a large improvement over RL05
  - Still some issues with low degree coefficients during single accelerometer months

- RL06 Mascons improve over RL05 Mascons
  - Better estimate of C_{20}
  - Improved agreement with AMOC LNADW transport
  - Reduction in residual noise in the solution
  - Reasonable estimates for low degree coefficients during single accelerometer months – this provides for better continuity with GRACE-FO

Backup

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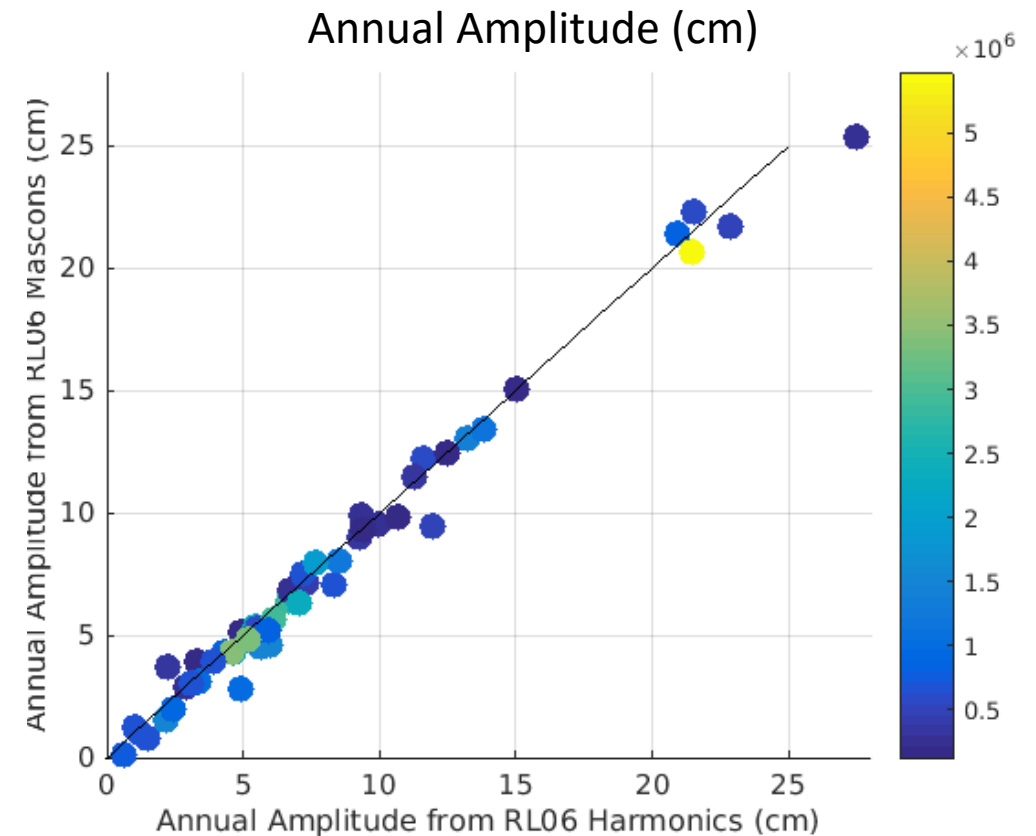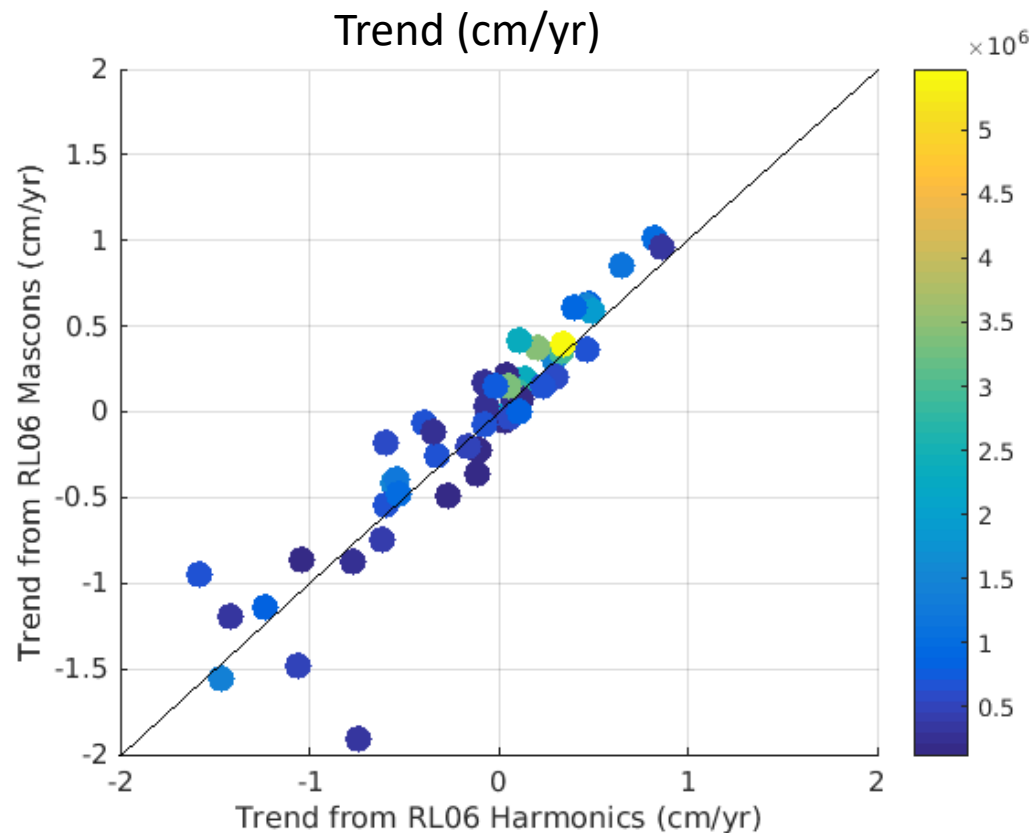
RL06 Mascons

- Improved estimates of single accelerometer months
  - Low degree coefficients are much more reasonable

- Small reduction in noise relative to RL05

- Better estimate of C_{20}
  - SLR-replacement still recommended

- RL06 is very much "in family" with RL05

- Updated GIA correction: ICE-6GD (Peltier et al., 2018)
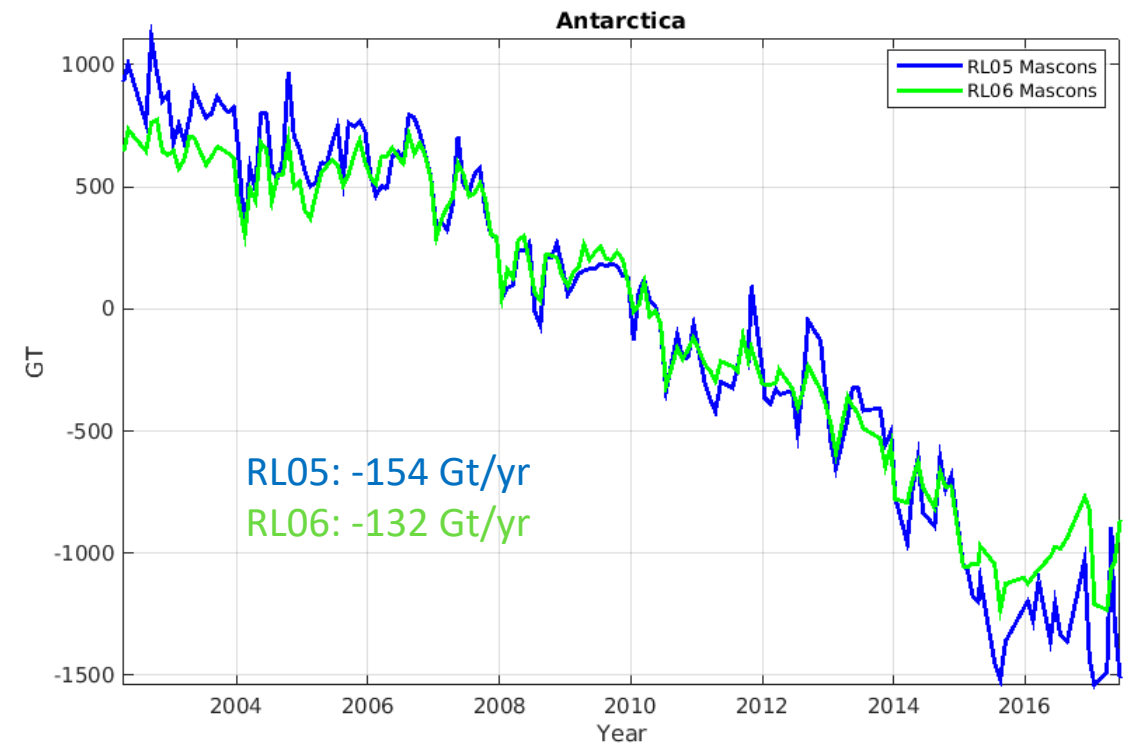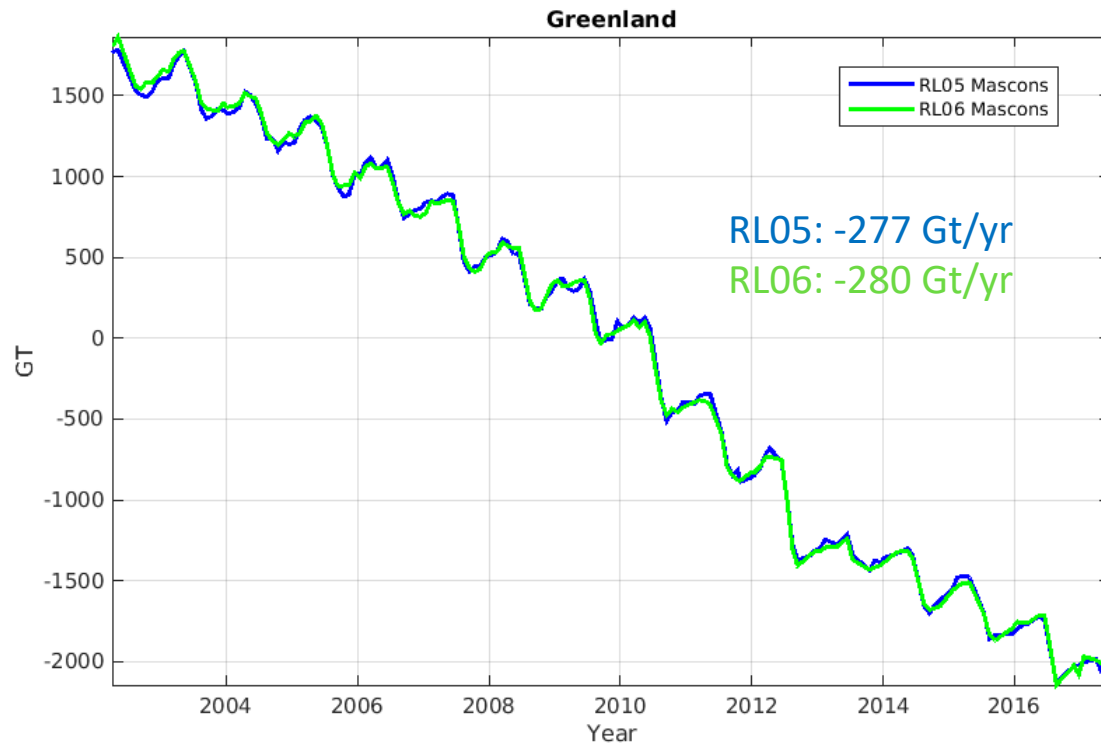

November 2007
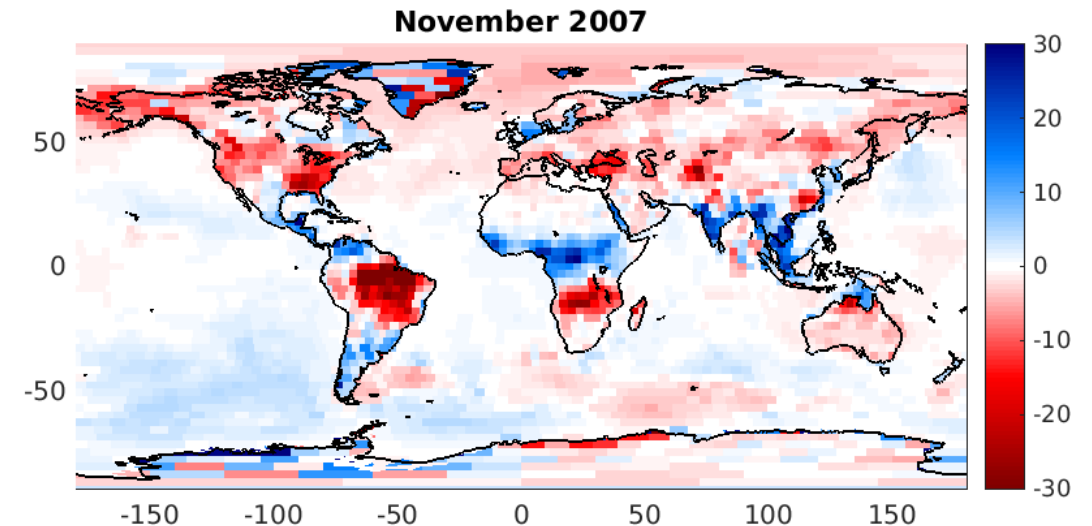
RL06 Mascons vs Harmonics
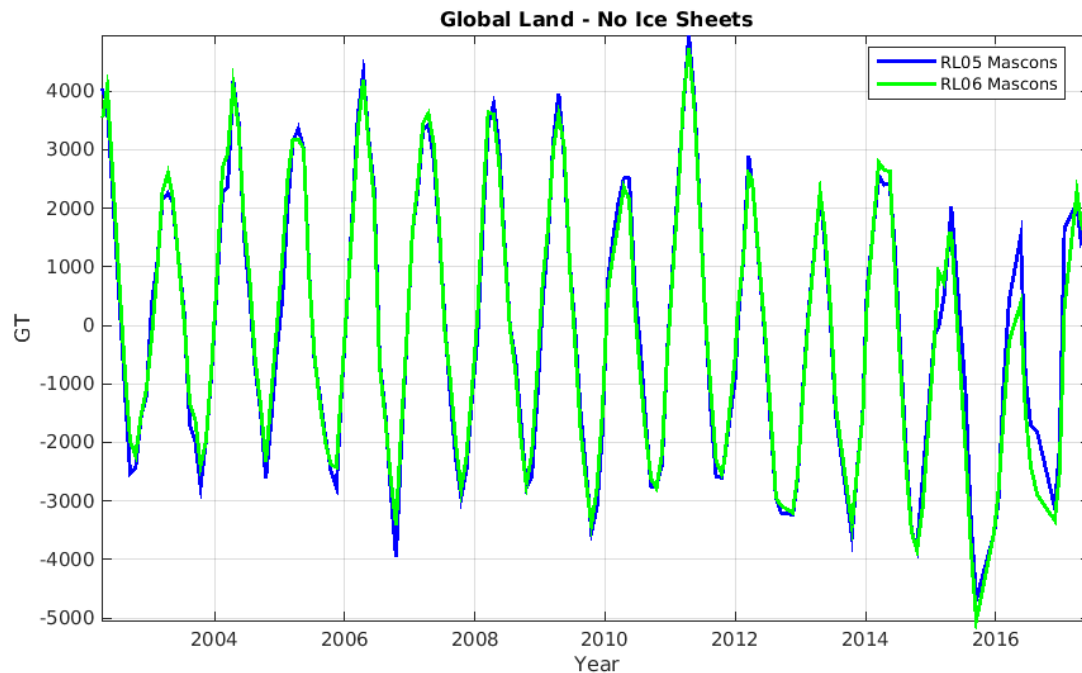
Comparison over 50 hydrological basins
Harmonics have been destriped and smoothed (300 km), and scale factors applied to both solutions
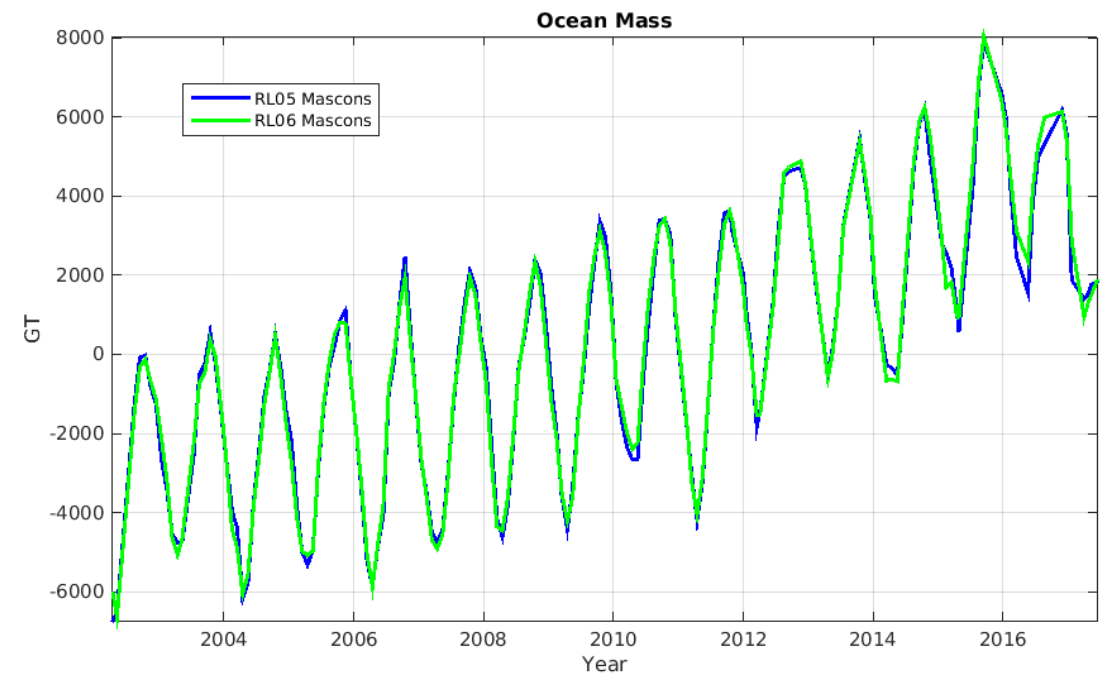

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Ice Sheets: RL05 vs. RL06

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